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W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

On the Photographs of the Corona at the Solar Eclipse of 1889, *January* 1. By Edward S. Holden, LL.D., Director of the Lick Observatory, Foreign Associate.

In the *Observatory* for March 1889, I have given a general account of the observations of the solar eclipse of January 1, 1889. I have also sent to the Royal Astronomical Society, in the name of the Lick Observatory, a positive copy on glass of one of the best negatives taken by Mr. Barnard of the Lick Observatory.

Since writing the letter in question I have been engaged in the preparation of a report on this eclipse, which will be printed by the University of California (of which the Lick Observatory is a part).

This report will contain the results of—

(*a*) Observations at the Lick Observatory (of the partial phase);

(*b*) Observations by the Lick Observatory field party at Bartlett Springs;

(*c*) Observations by an eclipse expedition sent out by the Amateur Photographic Association of the Pacific Coast;

(*d*) Observations by many other amateur observers.

One section of this report is nearly completed, and I have thought that it might be of interest to communicate this section (which deals with the representation of the coronal forms as obtained from photographs and drawings) in advance of the printing of the whole report, which may require several months for its completion. I therefore beg to present two careful drawings which I have made, and a portion of the section of the final report.

The drawings are: fig. 1—which I have compiled from the various photographs taken by Mr. Barnard of the Lick Observatory with an ordinary Clark achromatic of 3 inches' aperture and 49 inches' focus (stopped down to $1\frac{3}{4}$ inch); and fig. 2, which is a copy of the outer coronal forms only, as they are shown on two negatives taken with portrait cameras by Messrs. Ireland and Lowden of the Amateur Photographic Association. The figures speak for themselves; the section of the report follows immediately.

"*Diagrams of the Solar Corona from Photographs by E. E. Barnard of the Lick Observatory, and from Photographs by Messrs. Ireland and Lowden of the Amateur Photographic Association.*

"From the beautiful photographs of Mr. Barnard I have prepared the diagram or index map of the corona, which is given in fig. 1. One of Mr. Barnard's negatives was first copied in positive on glass, and a projection from this positive was thrown on a screen by a lantern. From this projection a careful drawing (Moon's diameter equal to $2\frac{5}{8}$ inches) was made. The positive was then examined by the transmitted light of a kerosene lamp through an opal glass shade under a magnifying glass, and the outlines obtained by projection were filled in. The parallel of declination, ecliptic, and vertex were then inserted from computations by Mr. Keeler. The Sun's axis is inclined 1° 24′ to the north and south line as drawn.

"It is necessary to say that in making this diagram no pictorial effect has been sought for. It was intended to show only the more important features and details exhibited in the negatives obtained by the Lick Observatory party. The fainter details shown in the diagram are, necessarily, relatively too plain. A number of the minor features are omitted to avoid confusing the drawing, and because they were not well seen on account of the small size of the original negatives (Moon's diameter equal $\frac{46}{100}$ inches). The principal features are numbered for convenience of reference, from 1 to 113. Near the lines extending from the centre of the Sun towards the east and west, I have placed a scale of minutes of arc, corresponding to the faint circles described about the Moon's centre. The diagram is least satisfactory in the region 35 to 38.

"We may say *à priori* that the phenomenon of the Sun's corona

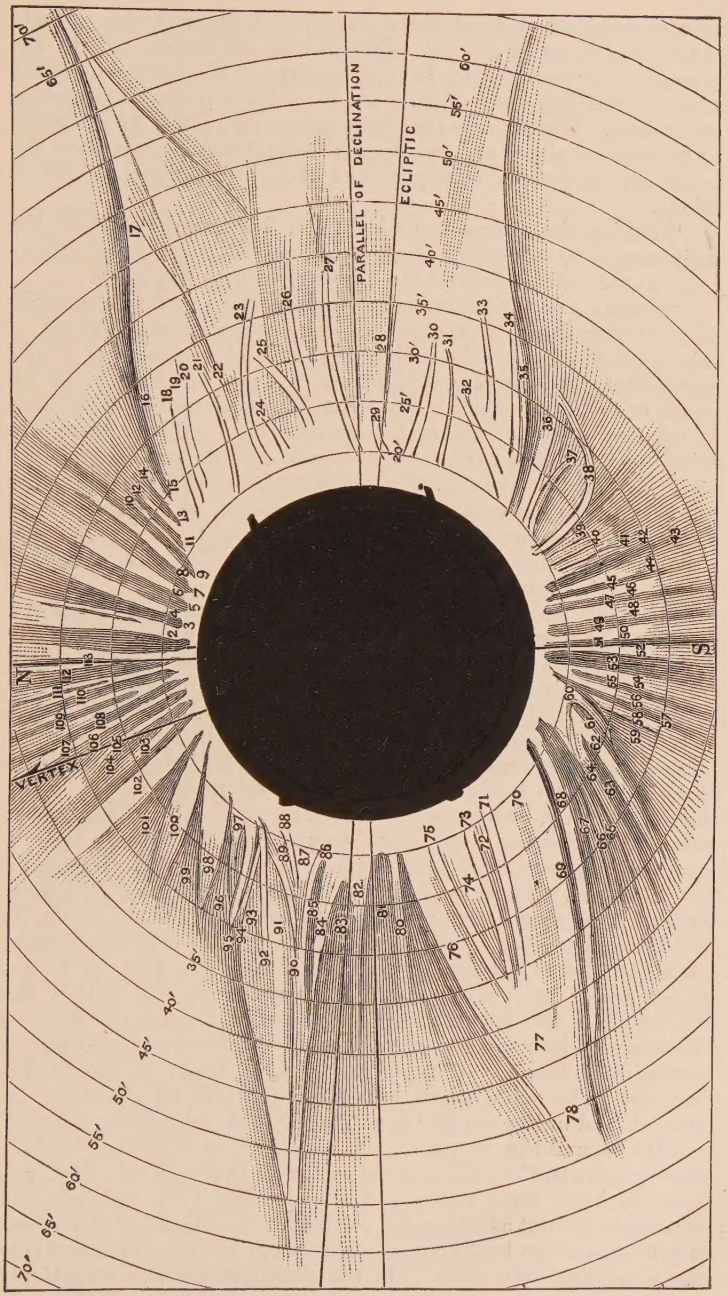


Fig. 1.—Diagram of the Solar Corona from photographs by E. E. Barnard, 1889, January 1.

is composed of at least three superposed appearances. There must be *first* some coronal effect due to diffraction &c. at the Moon's limb; *secondly* we have polar rays at the north and south poles of the Sun; and *thirdly* we have the equatorial wings or extensions. If we divide the phenomenon into parts by reference to brightness alone, and not simply as to structure, we have the inner corona (which is bright) and the outer corona (which is faint).

"Taking the corona as a whole, the first great result of the eclipse of 1889 is that *the characteristic coronal forms vary periodically as the Sun-spots (and the Auroras) vary in frequency.*

"Even a casual comparison of the drawings and photographs of 1889 with those of previous eclipses occurring at a period of minimum Sun-spots (the eclipse of 1867 and specially of 1878) shows that the characteristic forms of 1889 are typical of an epoch of minimum spots. The type for maximum spotted area is equally characteristic and very different. While there are minor features that vary from eclipse to eclipse, and do not seem to follow this law strictly, it appears that, broadly speaking, the eclipse of 1889 has established the correctness of the law above given, so far as our present data are sufficient. I believe that this law was first pointed out as probable by Mr. Ranyard (*Mem. R. A. S.*, vol. xli., 1879).

"We can best describe the parts of the corona as to extent and structure by reference to the index-map. The map shows the outer coronal wing at the south-east, extending as far as 78, or 55′ from the Moon's centre. At the north-west it extends fairly bright to 17, or 50′, and it can be traced to the 75′ circle by looking obliquely at the negatives, or by slowly moving them before a bright lamp with a porcelain shade. The south-west wing extends to the 50′ circle as fairly bright, and can be traced to 60′. The north-east wing, or ray, can be traced to 55′. All the important polar rays extend as much as 25′ to 30′ from the Moon's centre, and the longest ray (2) attains a length of 36′ in Mr. Barnard's best negative. There is little detail (except the four hydrogen flames) to be seen between the Moon's limb and the 20′ circle. It will be noticed that the south-west protuberance is in two distinct parts. A few of the narrow dark polar rifts (1, 3, 5, 7, 9, 43, 45, 47, 49, 51, 53, 57, 67, 69, 99, 101, 102, 103) end within the 20′ circle. The bright ring immediately around the Moon's limb may be in a small degree due to the chromosphere, but it seems likely that a certain portion of it, at least, is due to diffraction. The inner corona ceases to be bright at about 25′ in general, and in the wings 17, 30, 77, 92, the brightness falls off rapidly beyond the 30′ circle. A very curious feature of the best photographs is, that the coronal wings on the west side (20, 30) seem to have their north and south edges (16, 34) roughly parallel as far out as 45′ or 50′; while at this distance the edges (16, 17, 34) begin to diverge towards north and south respectively into a trumpet-like form. If the photographs are attentively

considered, they appear to show that the coronal beams inside the 50′ circle are gradually concentrating themselves. This seems to be their law as far as this point. It is therefore surprising to find at the 50′ circle the strongly marked tendency to divergent forms and to a trumpet-shaped extension. If the negatives did not show any portion of the wings beyond 45′ or 50′, it would be at once concluded from them that these extensions were convergent. But from the 50′ circle outward to 65′ and 75′ (on the west side of the Sun) the lines (16, 17, and 34) become strongly divergent, so that at the 65′ circle their distance apart (north and south) is already something like 45′.

" When I first discovered this in Mr. Barnard's negatives, I was inclined to doubt the position of the faint edges (16, 17, and 34), which I had laid down from the photographs, and I therefore sought for some evidence from the many drawings which had been sent to the Observatory for discussion.

" The drawings of Miss Robertson at Cloverdale, Mr. Staples at Bartlett Springs, Miss Silvia Rey at Cloverdale, Miss Nellie Treat at Cloverdale, Mr. C. Mason Kinne at Cloverdale, clearly indicate something of the trumpet-like extension referred to on the west side of the corona. In particular the sketch of Miss Treat shows an extension of the south edge of the south-west wing extending to 89′ from the Moon's centre. These drawings were all made without hiding the inner corona from the eye. The drawing of Miss Treat in particular agreed beautifully in direction with the line (34) of the photographs. The divergent character of the coronal wings on the west side of the Sun is completely proved by the photographs and by the drawings referred to, and the line (35, 34) can be drawn as far as 65′ with no doubt whatever, and with considerable confidence as far as 89′ from these two authorities alone. Fortunately for the question, the Observatory possesses a large number of photographs made by the members of the Amateur Photographic Association (see the reports in Part III.). A large number of these yield important evidence on the question of the extension of the outer corona, especially those of Messrs. Lowden, Ireland, Dornin, Treat, Passavant, Grimwood, and Burckhalter. Two of them, however, made by Mr. Lowden and by Mr. Ireland respectively, are so remarkable and so conclusive that we need only consider these two in order to obtain an entirely satisfactory portrayal of the outer coronal beams. It must be remembered that no previous photograph of the corona has extended beyond 50′ from the Sun's centre, so far as I know, and we are now concerned only with the description of the corona beyond the circle of 65 minutes. As I have said, the photographs of Mr. Barnard, together with the drawing of Miss Treat, carry the outlines of the outer corona out beyond the 80′ circle. The photographs of Mr. Ireland and Mr Lowden are naturally wanting in detail near the Sun, but beyond the 60′ circle they seem to carry the outlines of the four coronal wings as far as 135′ and 165′ respectively.

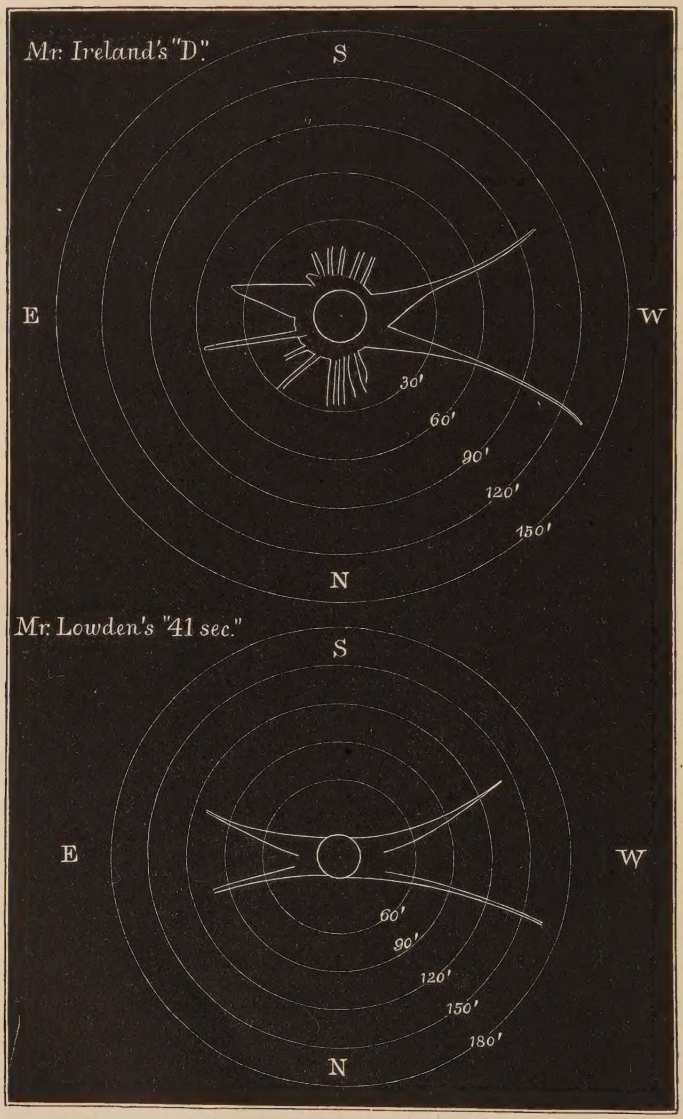


Fig. 2.—Diagrams of the Outer Corona, 1889, Jan. 1, from photographs by Messrs. Ireland and Lowden.

" The shortest way to present the evidence of these pictures is to copy their main outlines, which I have done in fig. 2. The scale is different for the two figures, but the circles concentric with the Moon's centre will serve as means of comparison. The

copies have been made from positives (and are reversed north and south from the index-map of Mr. Barnard's pictures, as all measurements with the compasses had to be made on the glass, and not the film-side). A very summary examination of the pictures will show plainly that the wings *certainly* extend as follows:

	Ireland	Lowden.
The north edge of the N.W. wing	96′	83′
The south edge of the S.W. wing	94′	79′
The axis of the S.E. wing	69′	69′
The axis of N.E. ray or wing	79′	76′

Mr. Lowden's second plate (21 secs.) gives these distances, to which the wings are obvious, as 89′, 69′, 66′, 85′ respectively.

"If the pictures are held obliquely in a strong soft light, or moved gently in front of such a light, these limits are very much extended, and I am satisfied that the drawings in fig. 2 would be verified by anyone who will give the requisite attention. The appearance of the planet *Mercury* on Mr. Lowden's plates shows that the camera (which was kept pointed by hand by means of a finding telescope) did not follow the Sun exactly. In spite of this fact the extension of the outer corona is extremely great, as we have seen. If this camera had been accurately driven by clockwork we should have had even more detail and extent than they now show, remarkable as this is. It should be said that Mr. Ireland's 'D' shows the detail of the polar rays and of the inner corona much better than the others (where these were lost by imperfect driving of the camera during the long exposures), and it accordingly seems that Mr. Ireland's experiments as to light, exposure, plates &c. should be repeated at some future eclipse. It thus appears that the new feature of the corona which just begins to show plainly in the photographs by Mr. Barnard, and in the drawing of Miss Treat, is very satisfactorily portrayed in the negatives taken by Messrs. Lowden and Ireland at different places and with different instruments. Many other negatives by members of the Pacific Coast Amateur Photographic Association lend independent corroboration to the conclusion already drawn. I may also cite a beautiful negative by the Rev. Father Charroppin, which extends nearly as far, is full of detail, and entirely confirms the existence of the trumpet-shaped extension of the outer corona. It is worthy of note that the drawings of the outer corona by Professors Newcomb and Langley at the solar eclipse of 1878, which show the outer corona extending several degrees on each side of the Sun, present no evidence of the branching forms shown in the negatives just described.

"There is no connection proved by this drawing between the prominences and the streamers, and a direct connection of this kind is probably *à priori* unlikely. It must, however, be said that the four chief prominences visible are at or very near the bases of characteristic coronal forms as they appear in the drawing.

"There are a few constantly recurring types of coronal structure. The polar rays exhibit the most pronounced type, perhaps. At the North Pole the bright rays (98, 100, 102, 103, the lower part of 105, 108, 110, 111, 113; 2, 4, 6, the lower part of 8, &c.) are essentially of one type. They extend nearly radially near the poles with a tendency to be convex towards the Sun's axis prolonged to the north. 105 is curved and convex to the axis, while 8 is strongly concave in all of Mr. Barnard's negatives. (This is quite different in the Harvard College positive, which has been kindly presented to the Lick Observatory by Mr. W. H. Pickering. I have drawn Prof. Pickering's attention to this difference, and a careful examination of the negatives of the Harvard College and the Lick Observatories will be made to decide whether in fact one of the coronal forms changed its shape between the instants corresponding to our respective negatives.)

"Many of the bright polar rays are doubled, as 109, 111, 113, 2, &c. The doubling in many cases does not appear to be due to a perspective projection of one ray upon another, but, so far as mere looks are concerned, the duplicity appears to be structural. We must of course imagine the whole area of the Sun's surface near the poles to be bristling with a network of these radial beams, whose analogy to the Auroral beams on the Earth is most marked. At the south pole of the Sun the same type occurs in 68, 67, 64, 62, 58, 56, 54, 52, 50, 48, 46, 44, 42, 41, 40, 39, 38, 37 (which has contrary curvature), 36, 35, &c. The centre of radiation of each set does not appear to be at the Sun's centre. The dark rifts between the bright rays are usually fairly straight in general direction. Their sides are not rectilinear, however, when attentively examined, and their roots are singularly terminated (notably in the case of 1). The bright polar rays projected near the south pole are in general straighter than those at the north (which was turned away from the Earth on January 1).

"I have said, in what precedes, that we must conceive the whole surface of the Sun near the two poles to be bristling with these Auroral (?) streamers, and this is the usual view of the matter. I see no reason, however, for supposing that such rays are confined to regions near the two poles. On the other hand the rays, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, on the west side of the Sun, and 80, 82, 94, 95, 97, 98 on the east side, appear to me to be of the same general nature as the bright polar rays. They are nearly always curved (though 80 and 82 are marked exceptions), and in general they are curved towards the Sun's equator. If we examine the lines of force at the poles of a bar-magnet there is no discontinuity between the families of rays at the ends of the magnet and those at the sides; and in the case of the Sun also, the so-called 'polar' rays appear to extend all around the disc. There is no latitude at which we can say that here the polar rays end, and a new species—equatorial rays

—begins. For example, 58 is a polar ray; so is 64; so, it seems to me, is 80 in all but situation. Again, what is to distinguish 6, 8, 10, 12, 14 (which are all of the polar type), from 23, 25, 26, except their curvature and their situation?

"The equatorial rays are all projected, it must be remembered, on a bright background, which does not exist at the poles. If this background were removed, we should, I think, at once see that the typical polar rays do in fact extend all round the disc, being least plentiful at the solar equator. I would therefore consider that the first characteristic type of structure consists of rays ordinarily called 'polar,' which are not connected with any bright background, and of such others (as 80 and 82 for example) as have no connection with the wing-like extensions.

"It is clear that there is a second type of rays which are connected with the wing-like forms. The best examples of these are 71, 73, 75, 84, 86, 88, 90, and probably 18, 19, 20, 21. These give the peculiar striations to the wings. A very interesting recurrence of a type is shown in the cases of 23, 24, 25; 36, 37, 38, and 86, 88, 90, and perhaps at 60, 61, 62. The symmetric arrangements of these groups is noteworthy. It is interesting also to observe that the two darkest and narrow polar rifts are nearly opposite to each other. I have found no cases of curved rays which bend completely over as in Mr. Wesley's diagram of the eclipse of 1871 (*Monthly Notices R.A.S.*, vol. xlvii. p. 501).

"As is well known, the solar spots occur chiefly in two zones extending from 5 to 40 degrees of solar latitude, north and south. A few spots occur near the solar equator, none beyond 45 degrees of latitude. Carrington's observations (1853–1861) show the greatest number of spots to be in latitudes 20° N. and S. Spoerer's observations (1861–1867) show the greatest numbers in latitudes 10° N. and S. The wings of the corona of 1889 have their axes about as follows, if we suppose them to lie in the plane perpendicular to the line of sight:

NW. wing,	axis in	latitude	48° N.
S.W.	,,	,,	14 S.
S.E.	,,	,,	28 S.
N.E.	,,	,,	20 N.

"It is possible that the connection of such wing-like extensions with the zones of maximum spots has been too hastily assumed. . . ."

The Trapezium of Orion. By S. W. Burnham, M.A.

Perhaps no object in the sidereal heavens has received more attention from astronomers than the multiple star *θ Orionis*. It has been the subject of careful study by the most eminent observers, provided with the best astronomical instruments; and the relative positions of the principal stars have been determined with the greatest possible accuracy. Certainly no equal area in any other part of the sky has furnished room for the location of so many purely imaginary stars. At intervals during the last fifty years various observers have recorded a number of stars in the space enclosed by the four bright stars of the trapezium. As a rule these alleged discoveries have been made with small telescopes, even down to four inches' aperture, and by observers with little or no experience in double-star work. As would be expected, perhaps, in an object as carefully studied as this has been for the last twenty or thirty years, all the large and most perfect modern refractors, directed by the most experienced double-star observers, have utterly failed to show, under the best atmospheric conditions, the least trace of a single one of the dozen or more supposed new stars. The great 26-inch at Washington, until recently the most powerful telescope in the world, revealed nothing to Hall in the course of a long series of measures of the known stars of this group. The other large telescopes in this country—the McCormick 26-inch, the Princeton 23-inch, the Chicago 18½-inch, the Madison 16-inch, and the Harvard 15½-inch—were equally unsuccessful.

The trapezium was carefully examined by me with the Chicago telescope, at times under very favourable circumstances, and as the result of the search for the new stars (*Mem. R.A.S.* vol. xliv. p. 99) I stated:—

"Several observers have seen, or believe they have seen, minute stars in the trapezium. . . . While making the measures given above, and at other times, under very favourable conditions, the interior of the trapezium and the vicinity of the principal stars were carefully examined. There was not the slightest suspicion of any additional stars. If the sixth star itself had been double, with a distance of 1″, it could not have been overlooked. I have very little faith in the real existence of these suspected stars after the failure of this and other large refractors to show them. It is wholly improbable that they should be variable in such a manner as to render them at all times invisible within the last few years. In regard to the alleged variability of the fifth and sixth stars, I can only say that they have always been readily seen with my 6-inch in the last six years when the atmospheric conditions were suitable. So far as my observations go there appears to be no evidence of change in the light of these stars."

Hall, after giving an elaborate series of measures of the principal stars (*Washington Observations*, 1877), states, "During my observations I never saw any star within the trapezium, and several careful examinations were made."

And yet one observer with a 12-inch mirror has recorded, "In the trapezium nine stars certainly, ten probably, were visible;" all of which is sufficiently indefinite to anticipate any real discovery now or hereafter. In fact it would be impossible to place a star within the trapezium which could not be claimed as identical with some of the stars referred to.

It is not difficult to understand how, in a region of this character, with a nebulous background, and surrounded by bright stars, faint points of light might be suspected; but it is past comprehension that the observer, before making any announcement, should not satisfy himself by repeated observations of the actual existence of the suspected stars, and, having done that, should not have attempted to fix their places by some tangible evidence. Apparently there has never been any effort to determine their positions by micrometrical measures, and we have only diagrams and descriptions, more or less vague, from which to locate the suspected objects. Examples of this kind are found in the imaginary companions to *Vega*, ϵ *Lyræ*, *Polaris*, *Sirius*, &c., which have long been known to be purely mythical. Mr. Sadler has carefully compiled the observations relating to new stars within the trapezium (*English Mechanic*, Jan. 13, 1882), and given in a diagram, as accurately as possible, the places of the several stars.

When the 36-inch refractor of the Lick Observatory was mounted, one of the first objects examined by Mr. Alvan G. Clark, the maker of the object-glass, was the trapezium of *Orion*; and he detected at once an exceedingly faint point of light within the trapezium, and nearly equidistant from the large stars C and D. Since that time this star has been repeatedly seen and measured by me, and, although a difficult object with the great telescope, there is certainly no doubt of its reality. It is not very far from the limit of a 36-inch aperture, and can only be seen with this instrument in a very good, steady air. It will stand very little magnifying, and is best seen with the lowest micrometer eye-pieces, powers 390 and 450. I have called the magnitude of this star 16, but I think the brightness is really over-estimated, the limit of the instrument being 17·0 on Argelander's scale. I have never seen with this or any other telescope so faint a star, or one so difficult to measure. It would be overlooked by any but the most careful observer even with this telescope on the very best nights, and is absolutely invisible to me when the seeing is not first class.

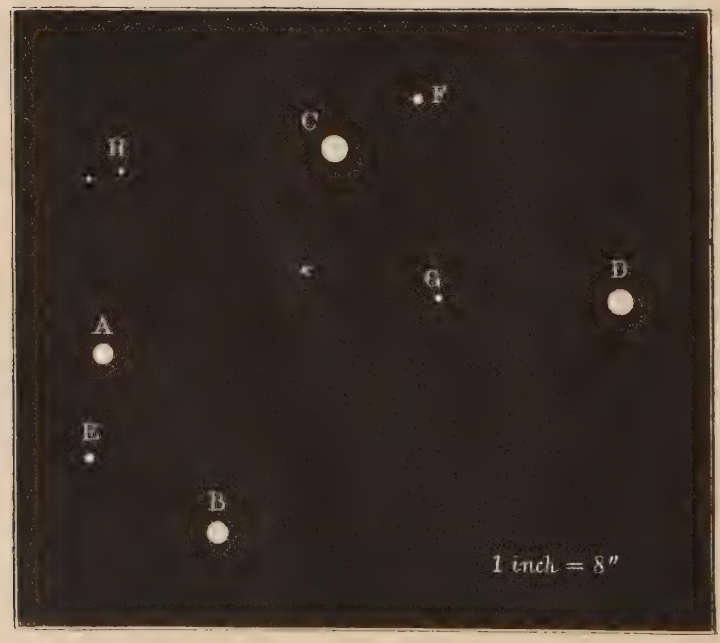
In October of the past year Mr. Barnard, of this Observatory, detected another new star just preceding the trapezium, which had been missed by all who had examined it with this telescope. It is about the same magnitude as the Clark star, and quite as

difficult to measure. He also saw that this exceedingly faint star was itself double, but I was unable to see the two components on any night when it was measured from the bright stars of the trapezium. Later, and on a remarkably perfect night, I saw the minute pair well, though with great difficulty, and obtained a fairly good measure. As a double star it is quite unlike anything known in the heavens, and the severest possible test for the defining and illuminating power of the large telescope. I have only been able to see it once.

No one who had seen either the Clark or the Barnard star with this instrument would for a moment doubt that they are beyond the reach of all other large telescopes. Possibly the Nice 30-inch may show them, but, from the difficulty of the observations here, I think it very improbable. The 30-inch at Pulkowa may be too far north.

Mr. Barnard has also discovered a second star within the trapezium, more centrally placed than the other, of the existence of which he has no question, having seen it on two occasions. I have not satisfactorily seen this star, and cannot speak of it from personal knowledge, but, from Mr. Barnard's great experience in studying very faint objects and his remarkable acuteness of vision, I am confident this new star will be found where he saw it, nearly on the diagonal from B to C. Down to this time I have found no night perfect enough to deal with it. It is certainly very much fainter than either of the other stars.

The accompanying diagram, drawn to scale (1 inch = 8″), will



indicate the relative positions of the several stars as derived from my measures. The unmeasured new star is indicated by a small cross.

The following measures were made by me with the 36-inch. The faint stars were usually measured with a power of 450, and the brighter stars with 670 and 1030. The Struve letters are used for the bright stars, the new stars being represented by the succeeding letters, and their magnitudes by the numbers in the fourth column :—

C and G. (Clark's star.)

1888·856	31°·7	7″·66	
1888·928	32·7	7·31	. . . 16
1889·049	37·9	7·81	
1889·077	32·6	6·83	. . . 16
1888·98	33 9	7·40	

D and G.

1888·856	273·1	7·45	
1888·928	267·9	7·12	
1889·049	272·1	6·56	
1889·077	269·1	6·99	
1888·98	270·5	7·03	

A and H. (Barnard's star.)

1888·928	178 6	7·74	. . . 16
1889·077	178·2	8·14	. . . 16
1889·00	178·4	7·94	

C and H.

1888 928	275 1	9·17	
1889·049	276·1	8·41	
1889·077	275·7	8·29	
1889·02	275·6	8·62	

H^1 and H^2. (Barnard's pair.)

1889·073	274·0	1·32	. . 16...16·5

Excessively difficult.

A and B.

1888·862	31 8	8·66	
·879	32·3	8·86	
·895	32·7	8·70	
1888·88	32·3	8·74	

A and C.

	°	″
1888 862	131·5	13·00
·879	131·2	13·06
·895	131·1	12·79
1888·88	131·3	12·95

D and C.

1888·856	241·7	13·23
·862	241·1	13·48
·879	241·1	13·35
1888·87	241·3	13·35

D and B.

1888·862	299·4	19·35
·879	299·4	19·33
·895	299·7	19·50
1888·88	299·5	19·39

B and C.

1888·862	162·9	16·87
·879	163·3	16·70
·895	162·7	16·71
1888·88	163·0	16·76

A and D.

1888·862	95·3	21·57
·879	95·5	21·55
·895	95·4	21·54
1888·88	95·4	21·55

A and E. (Fifth star.)

1888·862	352 0	4·28
·879	352·4	4·30
·895	350·1	4·36
1888·88	351·5	4·31

C and F. (Sixth star.)

1888·854	121·3	4·05
·856	121·8	4·06
·862	119·5	3·86
1888·86	120·9	3·99

As a test of the consistency, if not the accuracy, of the measures of position-angles, the following may be of some interest :—

Trapezium ABCD.

Angle A =	99°0
B =	92·8
C =	110·0
D =	58·2
	360·0

Triangle ACD.

Angle CAD =	35°9
ACD =	110·0
ADC =	34·1
	180·0

Triangle ADB.

Angle BAD =	63·1
ABD =	92·8
ADB =	24·1
	180·0

Triangle CDG. (Clark's star.)

Angle DCG =	27°4
CDG =	29·2
CGD =	123·4
	180·0

Triangle ACH. (Barnard's star.)

Angle CAH =	47°1
ACH =	35·7
AHC =	97·2
	180·0

The absence of any sensible change in the relative positions of the principal stars will be apparent from a comparison of these with the earlier measures of Struve and others. The number of nights of observation is given in the fourth column.

A and B.

1836·15	31°6	8″71	3n	Struve.
1873·69	31·8	8·61	2n	O. Struve.
1878·17	33·5	8·80	6n	Hall.
1888·88	32·3	8·74	3n	Burnham.

A and C.

1836·15	131·6	13·00	3n	Struve.
1868·20	132·4	13·25	5n	O. Struve.
1878·14	130·7	13·20	7n	Hall.
1888·88	131·3	12·95	3n	Burnham.

		D and C.		
1836·15	240°3	13″34	3n	Struve.
1868·20	241·8	13·41	5n	O. Struve.
1878·16	241·5	13·41	7n	Hall.
1888·87	241·3	13·35	3n	Burnham.
		D and B.		
1836·15	299 4	19·23	3n	Struve.
1873·69	300·2	19·29	2n	O. Struve.
1878·17	299·2	19·39	6n	Hall.
1888·88	299·5	19·39	3n	Burnham.
		B and C.		
1836·15	162·1	16 85	3n	Struve.
1868·20	163·6	16·89	5n	O. Struve.
1878·16	162·5	16·77	7n	Hall.
1888·88	163·0	16·76	3n	Burnham.
		A and D.		
1836·15	95·4	21·41	3n	Struve.
1872·20	95·2	21·40	3n	O. Struve.
1878·17	95·6	21·67	7n	Hall.
1888·88	95·4	21·55	3n	Burnham.
		A and E.		
1832·53	353·6	3·86	7n	Struve.
1859·62	350·8	4·29	4n	O. Struve.
1877·10	351·5	4·21	4n	Hall.
1888·88	351·5	4·31	3n	Burnham.
		C and F.		
1846·66	125·9	3·28	2n	Struve.
1858·85	128·8	3·93	5n	O. Struve.
1877·10	120·	4·00	4n	Hall.
1888·86	120·9	3·99	3n	Burnham.

The trifling differences in the measures of the fifth and sixth stars are undoubtedly due to errors of observation. As a multiple star it is wholly wanting in interest so far as relative motion is concerned.

Mount Hamilton:
1889, *March* 1.

Probable Errors of Greenwich Determinations of Right Ascension at different Zenith Distances. By A. M. W. Downing, M.A.

The observations used in computing these probable errors are chiefly those made in the years 1886 and 1887. In some of the groups observations made in 1885 have also been included. For the close polar stars, which are used for determination of the azimuth error of the Transit-Circle, the observations made in the years 1880–87 have been utilised, in order to get a sufficient number of observations of each star. As these stars were observed by the eye-and-ear method, the results for them are placed in a separate table, as not being comparable with the results obtained for stars observed by the chronographic method. In Table II., giving the results for south stars, I have added, for comparison, the probable errors computed by Mr. Dunkin from the Greenwich observations for 1857, printed in the *Monthly Notices*, vol. xx. p. 88. In the case of *Polaris* (Table III.) it was found that the probable errors deduced from the observations in 1885–87 were distinctly smaller than those found for the other azimuth stars from the observations made in 1880–87. It was thought that this might possibly arise from a change in the method of observing these close polar stars introduced at the beginning of 1885, viz. moving the system of vertical threads by means of the micrometer screw during the star's transit, so that a considerably greater number of separate observations could be obtained at the same transit than was formerly possible. The probable errors for *Polaris* were therefore computed afresh from the observations made in 1880–82, and these, although slightly larger than the former values, are still distinctly smaller than the values obtained for the other close polar stars. It would appear, therefore, that the determinations of right ascension of *Polaris* are more accurate (as estimated by discordance from the mean) than those of the other close polar stars which are used for determination of azimuth error. It will be remembered that the deduced right ascensions of these stars depend on azimuth errors determined from at least two consecutive transits of *Polaris* and *Polaris S.P.*, and are therefore independent of the assumed place of that star.

TABLE I.

Circumpolar Stars.

N.P.D. (Above Pole.)	Z.D. (of middle of Zone).	P.E.	P.E. × sin N.P.D.	No. of Obs.
° °	°	s	s	
50–45	9	±0·044	±0·032	131
45–40	4	·038	·026	135
40–35	1	·040	·024	134
35–30	6	·050	·027	136
30–25	11	·079	·036	133
25–20	16	·101	·039	86
20–15	21	·092	·028	74
15–10	26	·146	·032	53
10–5	31	·165	·022	26
(Below Pole.)				
5–10	46	·189	·025	43
10–15	51	·150	·032	57
15–20	56	·107	·032	80
20–25	61	·087	·033	113
25–30	66	·074	·034	82
30–35	71	·063	·034	77
35–40	76	·064	·039	74
40–45	81	·065	·044	61
45–50	86	±0·056	±0·041	13

TABLE II.

South Stars.

N.P.D.	Z.D. (of middle of Zone).	P.E.	P.E. × sin N.P.D.	No. of Obs.	Dunkin's Results.
° °	°	s	s		s
50–55	14	±0·034	±0·027	135	±0·037
55–60	19	·044	·037	123	
60–65	24	·039	·035	135	·035
65–70	29	·041	·038	135	
70–75	34	·031	·030	135	·029
75–80	39	·035	·034	135	
80–85	44	·035	·035	135	·032
85–90	49	·031	·031	135	
90–95	54	·038	·038	135	·032
95–100	59	·035	·035	135	
100–105	64	·042	·041	134	·035
105–110	69	·037	·035	135	
110–115	74	·043	·040	133	±0·043
115–120	79	·048	·043	135	
120+	84	±0·052	±0·044	98	

TABLE III.

Azimuth Stars.

Star.	Above Pole. P.E.	Above Pole. P.E. × sin N.P.D.	Above Pole. No. of Obs.	Below Pole. P.E.	Below Pole. P.E. × sin N.P.D.	Below Pole. No. of Obs.
	s	s		s	s	
λ Ursæ Minoris	± 1·643	± 0 030	89	± 1·449	± 0·027	54
Polaris (1880–1882)	0·881	·020	135	0·985	·023	135
Polaris (1885–1887)	·824	·019	132	·827	·019	132
Cephei 51	·713	·035	59	·636	·031	102
δ Ursæ Minoris	± 0·482	± 0·028	111	± 0·537	± 0·032	52

The probable errors given above have been computed by taking the difference between each separate result for right ascension and the mean result for the year, as given in the "Ledger" section in the volumes of *Greenwich Observations*. From the squares of these differences the probable errors have been found by the usual formula.

Blackheath: April 1889.

On the Proper Motion of 85 Pegasi. By J. E. Gore.

Using Mr. Burnham's measures of the 9th magnitude comparison to this rapid binary star, in the years 1878–88, I have computed the following formulæ:

$$\rho^2 = 194{\cdot}0449 + 1{\cdot}491\,(t - 1874{\cdot}92)^2,$$
$$\sec\,(51^\circ{\cdot}25 - \theta) = 0{\cdot}0718\rho.$$

The following is a comparison between the measures and the positions computed from the above formulæ:—

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	″	″	″
1870·00	Brünnow	77·0	74·77	+2·23	15·0	15·17	+0·83
1878·54	Burnham	33·6	33·67	−0·07	14·40	14·61	−0·21
1879·27	,,	30·4	30·42	−0·02	14·96	14·91	+0·05
1880·57	,,	25·0	24·91	+0·09	15·41	15·54	−0·13
1881·54	,,	20·8	21·13	−0·33	16·29	16·10	+0·19
1882·77	,,	17·1	16·70	+0·40	17 34	16·91	+0·43
1883·537	Seagrave	11·27	14·37	−3·10	17·34	17·45	− 0·11
1888·69	Burnham	0·9	0·90	0·0	21·71	21·83	−0·12

The annual proper motion of the binary pair is therefore 1″·221 in the direction of position-angle 141°·25.

On an Error in Brünnow's Formulæ for Differential Refraction in Distance and Position-Angle. By W. H. Finlay, M.A.

My attention was recently drawn to the fact that the formulæ given by Brünnow and by Chauvenet for the differential effects of refraction on distance and position-angle do not agree, and on investigation I found that there is an error in Brünnow's formulæ.

After finding expressions for the differential refractions in right ascension and declination, he proceeds to deduce those in distance (Δ) and position-angle (π) by help of the formulæ

$$\left.\begin{aligned}\cos\delta(\alpha-\alpha') &= \Delta\sin\pi\\ \delta-\delta' &= \Delta\cos\pi\end{aligned}\right\}$$

but in differentiating the first equation he treats δ as a constant.

If these equations be differentiated, treating δ as a variable and substituting $\kappa\tan\zeta\cos\eta$ for $d\delta$, it will be found that the expressions for refraction in distance and position-angle agree exactly with Chauvenet's formulæ.

Royal Observatory, Cape of Good Hope:
1889, *March.*

Photographs of the Nebulæ M 81, 82, *and a Nebulous Star in Ursa Major.* By Isaac Roberts.

The photographs were taken on March 31, 1889, with an exposure of $3\frac{1}{2}$ hours. One is enlarged five times and the other fifteen times the negative, and they show that the nebula M 81 is of a spiral character, and so differs from the other nebulæ, which have been already photographed, and differs also from the written descriptions of it which have been published by Sir John Herschel and by the Earl of Rosse. Sir J. Herschel refers to it as a "remarkable object, extremely bright, extremely large, suddenly very much brighter in the middle, and with a bright nucleus." The Earl of Rosse confirms these statements, and adds that it extends about 8′ from the nucleus to the north and does not extend beyond the first two stars.

The photograph shows it to extend far beyond the two stars presumably referred to, and the negative shows that the nucleus, which has not a well-defined boundary, is surrounded by rings of nebulous or meteoric matter, and that the outermost rings are discontinuous in the n.p. and s.f. directions.

It is very noticeable that there are numerous stars, or, more probably, star-like condensations of the nebular matter, arranged symmetrically, and apparently incorporated with the rings. It

requires little stretch of the imagination, and we feel strongly tempted, to account for these extraordinary appearances by referring them to Mr. Lockyer's theory of the collision of streams of meteorites. In this case one stream would be coming from the n.p. and the other from the s.f. directions, the collision between them causing the formation of the dense and undefined nucleus as well as the vortex, as shown in the photograph.

The other explanation of the vortex would be that it is an optical illusion, caused by the outermost rings appearing discontinuous, owing to insufficient photographic power, either physical or instrumental, to show that the faint rings are continuous round the nucleus; but the vortex hypothesis seems at present to explain most satisfactorily all the appearances as they are presented on the photograph.

M 82.

This nebula is described by Sir John Herschel as a "beautiful ray," very bright, very large, and very much extended. Lord Rosse states it is a "most extraordinary object, at least 10′ in length and crossed by several dark bands."

The photograph, particularly the negative, shows it to be probably a nebula seen edgeways, with several nuclei of a nebulous character involved, and the rifts and attenuated places in it are the divisions of the rings, which would be visible as such if we could photograph the nebula from the direction perpendicular to its plane. We see it in section, and the upper and lower surfaces are very rugged, and suggest that the evolution of this stellar system has not proceeded so far as that of the *Andromeda* nebula; but I must refrain from pursuing further speculation, for we want fuller data.

Nebulous Star.

The star is in the s.f. quadrant, and is very bright. Shortly I shall be able to give to the Society the distances and triangulation of it and of the two nebulæ already described; but an important question has frequently arisen in my mind when examining this and several other nebulous stars that I have photographed in different parts of the sky. *Are they not the bright nuclei of nebulæ*, the rings around them being invisible to us by reason of either of the following conditions: 1st, condensation not having proceeded far enough to show the rings; 2nd, they may be too distant for us to see the rings; 3rd, greater optical power might show them, and we may hope that ere long the question may be satisfactorily answered by the means which are now available to us?

The photographs are placed in the Library.

A Catalogue of the Stars of the IV. Type. By T. E. Espin.

The following catalogue contains all the stars of type IV. known up to the present time. In addition to those given by Dr. Dunér (*Sur les étoiles à spectres de la troisième classe*, p. 22) there are those detected by Pechüle (*Expédition danoise pour l'observation du passage de Vénus*), by Konkoly (*Spectroskopische Beob. der Sterne zwischen* 0° *und* −15° *bis zu* 7·5*ter Grösse*), and by myself. The places have been brought up to 1890, and are taken (1) from *Dunsink Observations*, part iv., containing the "Mean Places of 321 Red Stars;" (2) from the D.M. and Südl. D.M.; and (3) from the *Catalogo General Argentino*. In a few cases the stars are not found in any catalogue of star places, and consequently the places must be considered as more or less approximate. The magnitudes are from the D.M. and Südl. D.M., and for stars still farther south from the *Catalogo General Argentino*, and when the star is in none of these from the original observations. In passing I may note that the magnitudes of red stars as seen in the 17¼-inch Reflector are higher than those of the D.M. In column five the following abbreviations are used: Secchi=Se.; D'Arrest=D'A.; Vogel=V.; Pechüle=Pe.; Pickering=Pi.; Dunér=Du.; Konkoly=K.; while my own observations are marked Es.

The mean magnitudes of the stars observed are as follows:—

Secchi*	...	...	6·7
D'Arrest*	..	...	7·0
Vogel*	...	...	7·1
Pechüle	...	...	7·3
Pickering	...	...	8·4
Dunér*	...	...	8·3
Espin	...	...	8·8

Of the 113 stars 29 only are south of the Equator. This, on the supposition of equal distribution in the northern and southern hemispheres, would make a total of 168 stars of type IV. in the whole heavens above the mean magnitude of 8·8. The number of them may be considered as fairly complete down to −21°, since from the Catalogue it will be found that from +0° to +21° there are 21, and from −0° to −21° there are 21. Many of the stars in the Catalogue are variable to the extent of a magnitude and with no regular period. The leading star of this class of variable is 19 *Piscium*.

* Dunér, *Sur les étoiles*, &c., p. 125.

No.	Schj., D.M., &c.	α 1890 h m s	δ 1890 ° ′	Mag.	Auth.	Note.
1	Schj. 3	0 14 5	+44 5·9	8·2	Du.	
2	+34°·56	21 42	+34 59·7	8·1	Du.	
3	+57°·165	48 22	+57 57·9	9·5	Es.	
4	Schj. 7	1 10 5	+25 11·3	7·0	D'A.	
5	Es. 230	26 27	+57 11·2	9·8	Es.	
6	+51°·575	2 19 12	+51 34·1	9·0	Es.	
7	+56°·724	42 22	+56 31·5	9·4	Du.	
8	+57°·647	42 51	+57 23·7	8·9	Du.	
9	+57°·702	3 2 57	+57 29·1	7·9	Pi.	
10	+47°·783	6 1	+47 26·5	9·0	Es.	
11	Schj. 27*a*	32 21	+62 17·5	7·0	Du.	
12	+61°·667	56 18	+61 32·0	7·5	Es.	
13	Schj. 41	4 39 49	+67 58·4	7·0	Se.	
14	+21°·702	41 14	+21 57·8	9·4	Es.	
15	+34°·911	41 59	+34 48·4	8·8	Es.	
16	+15°·691	44 19	+15 36·4	9·4	Es.	
17	Schj. 43	44 38	+28 20·3	8·1	Se.	
18	+38°·955	45 6	+38 18·9	8·8	Es.	
19	+22°·770	47 12	+22 35·5	9·2	Es.	
20	R Leporis	54 36	−14 58·3	var.	V.	
21	+38°·1010	55 48	+38 54·6	9·5	Es.	
22	Schj. 51	59 43	+ 1 1·5	6·0	Se.	
23	−5°·1174	5 3 24	− 5 39·3	8·7	Du.	Birm. 99
24	+35°·1046	11 48	+35 40·4	8·9	Es.	
25	+32°·957	14 49	+32 23·7	9·3	Es.	
26	S Aurigæ	19 51	+34 3·2	var.	Du.	
27	+7°·929	27 17	+ 7 3·8	8·2	Es.	
28	+68°·398	29 7	+68 44·3	9·3	Es.	
29	Schj. 64	38 29	+24 22·3	8·5	Du.	
30	Schj. 64*a*	39 6	+20 38·9	7·7	Du.	
31	Schj. 65	40 10	−46 30·2	7½	Pe.	
32	Schj. 64*c*	41 3	+30 35·4	8·5	Es.	
33	Schj. 72	6 4 3	+26 2·1	7·4	D'A.	
34	Schj. 73	6 38	+27 11·8	9·0	Du.	
35	+33°·1290	10 1	+33 14·6	9·1	Es.	
36	Es. 160	13 26	+47 44·6	8·7	Es.	
37	+3°·1214	16 36	+ 3 28·8	9·0	Es.	
38	+25°·1250	17 5	+25 4·2	9·5	Es.	
39	Schj. 74	19 12	+14 46 9	6·5	D'A.	

No.	Schj., D.M., &c.	α 1890 h m s	δ 1890 ° ′	Mag.	Auth.	Note.
40	Es. 243	6 19 44	+19 9·7	9·4	Es.	
41	+3°·1381	38 54	+ 3 25·7	9·3	Pi.	
42	Es. 247	46 59	− 7 0·5	8·8	Es.	
43	+6°·1462	52 30	+ 6 18·8	8·0	Es.	
44	−3°·1685	55 31	− 3 6·0	7·7	Es.	
45	Schj. 88	7 1 37	− 7 23·3	8·3	Es.	
46	Schj. 89	2 55	−11 45·6	7·6	Se.	
47	+14°·1594	6 13	+14 53·5	9·0	Es.	
48	+48°·1504	9 57	+48 42·0	9·0	Es.	
49	+25°·1641	13 55	+25 11·6	9·0	Es.	
50	−3°·1886	19 24	− 4 0·9	8·7	Es.	
51	−2°·2101	19 47	− 2 54·5	9·0	Es.	
52	+24°·1686	25 14	+24 44·8	8·2	Es.	
53	+2°·1715	30 23	+ 2 19·0	9·3	Es.	
54	+5°·1797	42 55	+ 5 41·9	9·0	Es.	
55	−13°·2247	44 35	−13 49·2	7·2	K.	
56	Schj. 103	53 15	−49 41·2	8	Pe.	
57	Pickering 26	57 1	−12 46·6	var.	Pi.	
58	Schj. 115	8 49 11	+17 38·5	6·5	D'A.	
59	T Cancri	50 23	+20 16·2	var.	Es.	
60	+11°·1954	52 17	+11 15·5	var.	Es.	
61	Schj. 124	9 45 59	−22 30·2	7·3	Pe.	
62	Schj. 125	50 56	−41 3·9	$7\frac{1}{2}$	Pe.	
63	Schj. 126	56 23	−59 41·4	$7\frac{3}{4}$	Pe.	
64	Schj. 128	10 7 4	−34 46·7	$7\frac{1}{4}$	Pe.	
65	Schj. 130	30 20	−38 59·6	5·9	Pi.	
66	U Hydræ	32 7	−12 48·8	var.	Se.	
67	+68°·617	37 25	+67 59·1	6·2	Du.	
68	Schj. 136	46 17	−20 40·0	6·8	Se.	
69	Schj. 145	12 19 37	+ 1 22·8	8·1	D'A.	
70	Schj. 152	39 57	+46 2·5	5·5	Se.	
71	Schj. 155*b*	52 6	+66 35·4	7·3	D'A.	
72	−2°·3638	13 4 3	− 2 47·9	8·3	K.	
73	V Coronæ	15 45 36	+39 54·2	var.	Du.	
74	V Ophiuchi	16 20 36	−12 10·6	var.	Du.	
75	Schj. 202	17 23 14	−19 23·0	7·8	Du.	
76	Schj. 205	38 29	−18 36·5	8·5	Du.	
77	+4°·3779	18 25 6	+ 4 18·6	9·5	Es.	
78	+36°·3168	28 32	+36 54·9	8·5	Du.	

No.	Schj., D.M., &c.	α 1890	δ 1890	Mag.	Auth.	Note.
		h m s	° ′			
79	−7°·4633	18 31 7	− 7 41·4	9·0	Es.	
80	+36°·3243	39 1	+36 51·3	7·5	Du.	
81	Schj. 219	43 57	− 8 1·8	7·1	Du.	
82	Schj. 221	51 56	+ 0 18·6	9·2	Es.	
83	Schj. 222	53 30	+14 12·9	9·0	Du.	
84	Schj. 222*c*	58 32	− 5 50·8	7·0	V.	
85	−16°·5272	19 12 51	−16 6 4	6·8	Es.	Holden 7
86	Schj. 229	25 28	+76 20·4	6·5	Se.	
87	+45°·2906	25 31	+45 49·1	8·6	Es.	
88	Schj. 228	28 1	−16 36·7	7·2	Se.	
89	+32°·3522	36 44	+32 22·8	8·0	Du.	
90	+43°·3425	53 40	+43 57·9	8·2	Du.	
91	+27°·3612	20 0 14	+20 20·2	7·8	Es.	
92	+47°·3031	6 7	+47 31·5	9·3	Du.	
93	+35°·4002	6 14	+35 37·6	9·5	Pi.	
94	Pickering 38	6 57	+35 47·1	var. (?)	Pi.	
95	+38°·3957	9 25	+38 23·8	8·7	Du.	
96	V Capricorni	10 40	−21 38·3	var.	Se.	Schj. 238
97	+37°·3876	14 28	+37 6·9	9·	Es.	
98	U Cygni	16 11	+47 32·8	var.	Du.	
99	+36°·4028	17 12	+36 33·2	9·5	Es.	
100	+37°·3903	17 24	+37 10·4	9·4	Es.	
101	+39°·4208	24 50	+39 36·7	9·2	Es.	
102	V Cygni	37 37	+47 44·9	var.	V.	
103	Es. 287	41 19	+44 27·7	8·5	Es.	
104	+45°·3271	43 7	+45 38·9	8·8	Es.	
105	Schj. 248*b*	21 18 16	+41 55·6	9·5	Du.	
106	S Cephei	36 35	+78 7·7	var.	Du.	
107	Schj. 249*a*	37 23	+35 0·5	6·2	D'A.	
108	Schj. 251	38 43	+37 30·8	7·8	Se.	
109	Schj. 257	51 8	+49 58·6	9·1	Du.	
110	+54°·2865	22 44 11	+54 31·7	8·5	Es.	
111	+58°·2586	23 18 56	+58 34·6	9·0	Es.	
112	19 Piscium	40 46	+ 2 52·6	var.	Se.	Schj.
113	+42°·4824	58 43	+42 59·6	8·6	Es.	

On a Method of Supporting a Large Mirror when Silvering.

By Edward Crossley, M.P.

On account of the recent construction of large reflecting telescopes, and their application to celestial photography, it seems important to record the means by which any difficulties in handling large mirrors have been overcome. I therefore venture to lay before the Society a description of a method of supporting and handling a 3-foot mirror when silvering. It differs from Sir Howard Grubb's method of handling a large mirror principally in having a groove in the edge of the mirror.

Two plates have cylindrical ribs fitting into the groove, with pivots on the outside; the plates are held in their places on two opposite sides of the mirror by a copper band passing over and rivetted to them. The band is cut in two at two points 90° from the pivots; the cut ends are then united by screw bolts. This renders it an easy matter to get band and ribs into their places. A stirrup with holes for the pivots to slip into is then put on; and to facilitate this the stirrup is cut in two at the top and the two halves secured by a screw bolt.

The band, pivots, plates, and ribs are of copper; the ends of the stirrup of aluminium bronze. All these are coated with silver, to protect them from the action of the silvering solution.

In the annexed figure M is the mirror, S the stirrup, *p* the pivots, *g* the groove, B the band.

In this way the mirror can be lifted and placed at any angle with the greatest ease and with perfect safety.

The groove round the edge of the mirror is $\frac{3}{16}$ in. in depth, the plates $8\frac{1}{2}$ in. by 3 in. by $\frac{3}{16}$ in.; the band is $1\frac{1}{2}$ in. in width and $\frac{1}{16}$ in. thick, but where it is rivetted to the plates it is of the same width as the plates.

The readiness with which the mirror can be set at any angle obviates the necessity for using a large quantity of silvering solution; and by setting the mirror at an angle of 7° and the silvering vessel at half that inclination the quantity of solution can be reduced to less than six gallons, at least ten gallons being required to get out all the air when the vessel is horizontal.

Observations of Comets made at the Orwell Park Observatory in the years 1888–89. By John I. Plummer, M.A.

Comet III. 1888 . . . (*Brooks, August* 7, 1888.)

1888.	Greenwich Mean Time. h m s	Comet—Star. Δα. m s	Δδ. ′ ″	No. of Comps.	Comet's App. R.A. h m s	Log (p × Δ).	Comet's App. Dec. ° ′ ″	Log (p × Δ).	Red. to App. Place. s	″	Comp. Star.
Aug. 29	10 5 20	−2 1·11	− 5 11·1	8–8	12 54 4·35	9·6155	+38 34 1·8	0·8454	−0·41	+6·9	1
Sept. 3	9 27 38	+1 40·26	+ 5 43·6	4–4	13 26 31·50	9·6337	+35 12 1·4	0·8119	−0·28	+7·6	2
6	9 31 7	−0 29·35	− 6 39·2	9–9	13 44 29·02	9·6235	+32 58 9·0	0·8168	−0·20	+8·2	3
11	9 50 1	+1 16·80	− 4 25·5	7–7	14 11 45·87	9·5998	+29 4 38·1	0·8357	−0·08	+8·6	4
12	9 28 8	+3 58·46	+ 4 38·4	6–6	14 16 44·64	9·6076	+28 18 26·5	0·8212	−0·07	+8·5	5
13	8 52 13	−0 34·21	+ 2 47·1	9–11	14 21 33·89	9·6128	+27 32 8·9	0·7960	−0·03	+8·8	6
26	8 25 41	+1 13·65	+ 0 42·0	6–6	15 16 13·32	9·5801	+17 39 58·5	0·8103	+0·18	+8·8	7
27	7 44 31	−0 42·03	+ 3 7·0	9–9	15 19 43·36	9·5642	+16 58 51·3	0·7932	+0·20	+8·8	8
30	7 35 30	+1 18·32	+ 4 48·3	8–8	15 30 3·29	9·5555	+14 55 16·7	0·7986	+0·23	+8·6	9
Oct. 1	7 47 4	+0 22·32	− 4 45·8	7–7	15 33 24·00	9·5608	+14 14 48·9	0·8059	+0·24	+8·6	10
5	7 58 3	−2 17·71	− 4 55·1	7–7	15 46 5·14	9·5622	+11 41 9·9	0·8190	+0·29	+8·5	11
7	8 19 52	+0 55·20	+ 1 12·6	3–3	15 52 7·42	9·5666	+10 28 13·5	0·8289	+0·30	+8·2	12
8	7 43 52	+1 15·45	+ 3 35·3	8–8	15 54 58·96	9·5550	+ 9 53 45·1	0·8208	+0·30	+8·1	13

August 29.—Interrupted by passing clouds. Observation not quite satisfactory.
September 12–26.—The comet fainter latterly as it approached the horizon.
September 13.—The comet rather faint, owing to moonlight.
October 1.—A faint star near to the nucleus made the bisections difficult and uncertain.
October 5.—Comet rather faint. October 7.—Obtained with difficulty when near the horizon and between clouds.

Comet 1889 . . . (*Barnard's, Sept.* 2, 1888.)

1888.	Greenwich Mean Time.	Comet−Star. Δα.	Comet−Star. Δδ.	No. of Comps.	Comet's App. R.A.	Log ($p \times \Delta$).	Comet's App. Dec.	Log ($p \times \Delta$).	Red. to App. Place.	Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Sept. 11	15 13 21	+1 12·55	− 9 19·6	8–8	6 50 56·47	$9{\cdot}5125_n$	+10 23 35·7	0·8035	+0·81 −0·7	14
12	15 2 49	+1 40·93	+ 4 14·1	8–8	6 50 40·97	$9{\cdot}5188_n$	+10 19 16·5	0·8056	+0·84 −0·5	15
13	15 3 21	+1 23·05	− 0 33·0	8–8	6 50 23·11	$9{\cdot}5139_n$	+10 14 29·4	0·8046	+0·86 −0·5	15
13	15 26 55	+0 5·42	+ 8 24·9	3–3	6 50 22·43	$9{\cdot}4869_n$	+10 14 28·0	0·7987	+0·86 −0·5	16
14	14 41 48	−0 13·22	+ 3 54·1	4–4	6 50 3·82	$9{\cdot}5297_n$	+10 9 57·1	0·8094	+0·88 −0·5	16
30	14 39 6	−1 12·73	− 1 10·2	8–8	6 39 57·05	$9{\cdot}4417_n$	+ 8 37 10·0	0·8011	+1·38 +0·1	17
Oct. 1	14 45 45	+0 49·13	− 1 37·1	8–8	6 38 56·00	$9{\cdot}4212_n$	+ 8 30 7·3	0·7996	+1·43 +0·2	18
2	14 39 56	−0 26·58	− 3 32·0	8–8	6 37 51·82	$9{\cdot}4227_n$	+ 8 22 58·8	0·8005	+1·46 +0·2	19
5	14 44 34	+1 26·76	− 3 51·8	8–8	6 34 14·71	$9{\cdot}3821_n$	+ 8 0 17·4	0·7993	+1·58 +0·4	20
6	14 41 43	+1 1·56	+ 3 4·4	8–8	6 32 54·83	$9{\cdot}3765_n$	+ 7 52 31·8	0·7997	+1·61 +0·5	21
7	14 48 36	+2 45·82	+ 4 42·7	9–8	6 31 29·92	$9{\cdot}3475_n$	+ 7 44 14·7	0·7990	+1·65 +0·7	22
8	15 7 45	+1 16·23	− 3 53·4	9–9	6 30 0·36	$9{\cdot}2785_n$	+ 7 35 38·6	0·7968	+1·68 +0·6	22
13	14 42 28	+2 40·15	− 3 49·0	7–7	6 21 25·99	$9{\cdot}2685_n$	+ 6 50 18·5	0·8017	+1·88 +1·0	23
14	12 21 40	−1 37·40	+ 6 58·3	8–8	6 19 38·29	$9{\cdot}5187_n$	+ 6 41 30·6	0·8208	+1·89 +1·0	24
15	14 39 34	+1 54·59	+ 0 51·3	9–9	6 17 21·79	$9{\cdot}2377_n$	+ 6 31 32·8	0·8028	+1·95 +1·2	25
30	12 6 17	−1 37·44	− 4 52·9	8–8	5 31 59·38	$9{\cdot}3738_n$	+ 3 16 24·7	0·8257	+2·51 +3·1	26
Nov. 9	11 4 58	+3 20·09	− 6 36·0	6–6	4 42 19·83	$9{\cdot}3035_n$	+ 0 15 6·4	0·8402	+2·84 +5·4	27
13	10 52 19	+0 6·97	+ 7 22·7	9–9	4 17 47·50	$9{\cdot}2128_n$	− 1 6 15·8	0·8472	+2·92 +6·2	28

October 30.—Comet faint, from fog and cloud.

1888.	Greenwich Mean Time. h m s	Comet—Star. $\Delta\alpha$. m s	$\Delta\delta$. ′ ″	No. of Comps.	Comet's App. R.A. h m s	Log $(p\times\Delta)$.	Comet's App. Dec. ° ′ ″	Log $(p\times\Delta)$.	Red. to App. Place. s ″	Comp. Star.
Nov. 20	11 30 21	+1 19·67	+7 30·7	9–9	3 30 10·37	8·0309	−3 28 30·9	0·8609	+2·97 + 7·6	29
22	10 51 0	−2 36·79	−9 46·5	8–8	3 16 21·86	8·2445$_n$	−4 5 39·3	0·8641	+2·97 + 7·8	30
23	11 28 43	+3 26·32	−9 52 9	9–9	3 9 11·63	8·7781	−4 23 50·9	0·8655	+2·95 + 8·2	31
26	12 39 9	−1 36·10	−3 55·9	7–7	2 48 10·46	9·3251	−5 13 47·0	0·8646	+2·92 + 8·4	32
Dec. 5	7 59 18	+2 49·02	+5 27·1	8–8	1 53 5·92	8·8880$_n$	−6 54 57·4	0·8770	+2·68 + 9·2	33
6	7 58 30	−1 39·57	+5 58·6	9 9	1 47 35·38	8·8042$_n$	−7 2 21·3	0·8778	+2·67 + 9·0	34
7	8 6 25	−2 27·36	+6 28·9	8–8	1 42 13·19	8 5608$_n$	−7 9 4·3	0·8788	+2·64 + 9·0	35
9	8 41 11	+2 36·81	+2 20·5	7–7	1 31 55·81	8·6829	−7 20 20·0	0·8795	+2·56 + 9·3	36
13	7 25 1	−1 31·54	−2 26·6	8–8	1 13 53·89	8·2955$_n$	−7 35 0·0	0·8809	+2·46 + 9·2	37
22	7 1 47	−4 23·44	+4 30·1	8–8	0 41 53 34	8·7067	−7 39 24·0	0·8808	+2·21 + 9·2	38
23	9 6 18	+3 28 97	+5 37·9	1–1	0 38 45 67	9·3814	−7 38 2·5	0·8709	+2·14 + 9·4	39
26	9 22 40	+1 23·00	+1 49·1	8–8	0 30 49·50	9·4490	−7 32 51·0	0·8659	+2·07 + 9·4	40
30	6 51 46	−1 58·77	+3 51·8	8–8	0 21 58·40	9·0620	−7 23 11·8	0·8780	+1·99 + 9·3	41
30	7 5 41	−4 11·21	+3 20·5	4–4	0 21 56·93	9·1346	−7 23 7·4	0·8772	+2·00 + 9·2	42
31	7 11 37	−1 32·17	−7 10·7	8–8	0 19 54·02	9·1873	−7 20 29·3	0·8761	+1·97 + 9·4	43
1889. Jan. 1	6 20 51	+1 6 46	−1 47·9	8–8	0 18 0·79	8·9335	−7 17 29·5	0·8784	−1·13 −10·6	44

November 20–22.—Very windy. Clock almost inaudible at times.

November 23.—Observation obtained with difficulty. Very high wind and passing clouds.

December 6.—Comet faint at times, owing to light cirrus clouds.

December 30.—A small star was almost coincident with the nucleus of the comet at the commencement of the observations. December 31.—Comet very faint, from haze.

1889.		Greenwich Mean Time. h m s	Comet—Star. Δα. m s	Δδ. ′ ″	No. of Comps.	Comet's App. R.A. h m s	Log ($p \times \Delta$).	Comet's App. Dec. ° ′ ″	Log ($p \times \Delta$).	Red. to App. Place. s	″	Comp. Star.
Jan.	20	6 28 45	+1 14·64	+ 2 18·0	8–8	23 53 18·57	9·3751	−6 2 29·0	0·8657	−1·47	−10·8	45
	27	6 46 8	−1 20·01	+ 0 53·1	8–8	23 48 20·42	9·4648	−5 30 31·9	0·8590	−1·53	−10·8	46
Feb.	4	6 55 47	+1 17·13	+10 30·2	2–2	23 44 18·84	9·5170	−4 52 48·4	0·8524	−1·62	−10·8	47
	8	6 35 8	+1 8·43	− 2 41·8	5–6	23 42 48	9·5137	−4 33 57	0·8523	−1·64	−10·8	48

Comet V., 1888 . . . (*Barnard's, October* 30, 1888.)

1888.												
Nov.	13	17 28 55	−1 27·17	− 9 36·1	7·7	10 2 29·56	$8{\cdot}9372_n$	−12 58 29·0	0·9008	+1·45	− 2·0	49
Dec.	6	15 53 56	+1 33·13	− 2 18·0	8–8	10 23 22·19	$9{\cdot}0935_n$	− 7 16 22·2	0·8771	+2·11	− 8·1	50
	7	15 47 7	−1 29·57	+ 6 36·6	8–8	10 23 55·03	$9{\cdot}1109_n$	− 6 57 19·0	0·8756	+2·12	− 8·4	51
	9	15 42 13	−2 8·49	+ 0 54·5	8–8	10 24 55·82	$9{\cdot}1005_n$	− 6 18 15·1	0·8729	+2·18	− 9·1	52
	12	15 49 7	+2 13·39	− 7 31·0	8–8	10 26 12·84	$8{\cdot}9970_n$	− 5 16 25·7	0·8689	+2·29	−10·1	53
	26	11 54 53	−1 7·41	+ 6 31·2	8–8	10 28 7·54	$9{\cdot}5035_n$	+ 0 20 26·2	0·8406	+2·71	−14·9	54
	30	12 2 45	−1 25·29	− 6 44·8	8–8	10 27 24·81	$9{\cdot}4750_n$	+ 2 13 28·5	0·8335	+2·83	−16·3	55

February 8.– Comet faint, from moonlight. The wind being very high the clock was heard with difficulty.
November 13.—Comet fairly bright, but overpowered by twilight latterly.
December 6.—Comet rather faint. Sky hazy. December 26. Comet faint and observation difficult.
December 30.—Comet faint and observation difficult, owing to the proximity of a small star.

1889.	Greenwich Mean Time. h m s	Comet—Star. Δα. m s	Δδ. ′ ″	No. of Comps.	Comet's App. R.A. h m s	Log (ρ×Δ).	Comet's App. Dec ° ′ ″	Log (ρ×Δ).	Red. to App. Place. s ″	Comp. Star.
Jan. 1	12 6 27	−1 21·17	+1 15·4	8–8	10 26 50·88	$9·4584_n$	+ 3 13 3·5	0·8289	−0·20 +1·5	56
3	11 21 51	+1 37·37	+5 30·4	8–8	10 26 9·22	$9·5043_n$	+ 4 12 53·7	0·8281	−0·13 +0·8	57
7	12 1 41	+4 41·65	−6 37·5	8–8	10 24 18·32	$9·4254_n$	+ 6 19 9·3	0·8122	−0·01 −0·6	58
27	10 14 6	+0 53·11	−4 48·4	8–8	10 8 0·67	$9·4648_n$	+17 29 18·3	0·7456	+0·46 −5·0	59
29	12 10 34	+1 43·47	−6 10·4	9–9	10 5 47·32	$9·0776_n$	+18 38 17·6	0·6921	+0·50 −5·2	60
Feb. 2	9 20 17	−1 43·42	−9 21·7	3–3	10 1 29·44	$9·5075_n$	+20 43 7·0	0·7331	+0·57 −5·5	61
4	9 52 31	−1 59·55	+4 13·6	8–8	9 59 12·69	$9·4441_n$	+21 46 27·6	0·7008	+0·61 −5·5	62
20	9 48 15	+1 23·80	−3 45·7	9–9	9 41 27·16	$9·2613_n$	+28 53 2·5	0·5694	+0·80 −4·3	63
Mar. 2	8 21 2	−1 53·02	−0 31·0	9–9	9 32 14·19	$9·3996_n$	+32 5 11·2	0·5478	+0·83 −2·7	64
3	8 16 43	−3 22·21	−3 57·8	8–8	9 31 26·65	$9·3997_n$	+32 21 14·5	0·5432	+0·83 −2·5	65
5	11 11 7	−1 41·63	+0 16·4	8–8	9 29 50·14	8·8949	+32 54 11·9	0·4643	+0·82 −2·1	66

January 1.—Comet fainter. January 7.—Comet faint and difficult to observe.
February 2.—Observation interrupted by clouds. February 20.—Observation not quite satisfactory.
March 3.—The comet appears to maintain its lustre in a remarkable manner and is not sensibly fainter than it was at the end of Januarv

Assumed Mean Places of Comparison Stars.

Comet III. 1888.

Comp. Star.	R.A. 1888·0.	Decl. 1888·0.	Authority.
	h m s	° ′ ″	
1	12 56 5·87	+38 39 6·0	⅓ (2 Arm.$_2$ 1513 + Lal. 24246).
2	13 24 51·52	+35 6 10·2	⅓ (2 B.W.$_2$ 456 + Lal. 24993).
3	13 44 58·57	+33 4 39·9	½ (B.W.$_2$ 932 + Lal. 25499).
4	14 10 29·15	+29 8 55·0	B.W.$_2$ 184.
5	14 12 46·25	+28 13 39·7	Equat. comparison with B.W.$_2$ 151, B.W.$_2$ 182, and B.W.$_2$ 238.
6	14 22 8·13	+27 29 13·1	Equat. comparison with B.B. vi. + 27°·2375 B.W.$_2$ 566.
7	15 14 59·49	+17 39 7·7	Equat. comparison with B.B. vi. + 17°·2848 and B.W.$_2$ 242. (Decl. doubtful.)
8	15 20 25·19	+16 55 35·4	½ (B.W.$_2$ 400 + Lal. 28135).
9	15 28 44·74	+14 50 19·9	Equat. comparison with B.W.$_1$ 447.
10	15 33 1·44	+14 19 26·1	B.W.$_1$ 598.
11	15 48 22·56	+11 45 56·5	½ (B.W.$_1$ 896 + Schj. 5628).
12	15 51 11·92	+10 26 52·7	B.W.$_1$ 944.
13	15 53 43·21	+ 9 50 1·7	Equat. comparison with B.B. vi. + 9°·3121 and 3139.
		Comet 1889.	
14	6 49 43·11	+10 32 55·9	Equat. comparison with B.W.$_1$ 1400 and B.W.$_1$ 1535. (There is no star in the place of Lal. 13302. Its R.A. appears to be that of B.W.$_1$ 1400, and its declination that of B.W.$_1$ 1423.)
15	6 48 59·20	+10 15 2·9	Equat. comparison with B.B. vi. + 10°·1335 and B.W.$_1$ 1414.
16	6 50 16·16	+10 6 3·6	B.B. vi. + 10°·1335.
17	6 41 8·40	+ 8 38 20·1	B.W.$_1$ 1193.
18	6 38 5·44	+ 8 31 44·1	Equat. comparison with B.W.$_1$ 1152 and B.W.$_1$ 1175.
19	6 38 16·94	+ 8 26 30·6	Equat. comparison with B.W.$_1$ 1175.
20	6 32 46·38	+ 8 4 8·7	Equat. comparison with B.B. vi. + 8°·1414 and 1417, and with B.W.$_1$ 823 and 841. (It has been assumed that the R.A. of B.B. vi. + 8°·1414 and 1417 is in each case one second too small.)
21	6 31 51·67	+ 7 49 26·9	½ (B.W.$_1$ 908 + Schj. 2291).
22	6 28 42·45	+ 7 39 31·3	14 *Monocerotis* ½ (Gr. 9 yr. 637 + Arm., 1502).
23	6 18 43·97	+ 6 54 6·4	B.W.$_1$ 489.
24	6 21 13·80	+ 6 34 31·4	B.W.$_1$ 576.

Comp. Star.	R.A. 1888·0. h m s	Decl. 1888·0. ° ′ ″	Authority.
25	6 15 25·25	+ 6 30 40·3	Equat. comparison with B.W.$_1$ 523.
26	5 33 34·31	+ 3 21 14·5	B.W.$_1$ 801.
27	4 38 56·90	+ 0 21 37·0	½ (Glasg. 1151 + Paris 5437). Proper motion, amounting to −0ˢ·013 in R.A. and −0″·07 in decl., is assumed provisionally by comparison with Lal. 8934 and B.W.$_1$ 808.
28	4 17 37·61	− 1 13 44·7	⅓ (Lam. 575 + B.W.$_1$ 324 + Lal. 8262).
29	3 28 47·73	− 3 36 9·2	⅙ (2 Glasg. 833 + 2 Paris 4227 + B.W.$_1$ 491 + Lal. 6608).
30	3 18 55·68	− 3 56 0·6	⅓ (2 Glasg. 791 + B.W.$_1$ 300).
31	3 5 42·36	− 4 14 6·3	⅕ (Glasg. 739 + Arm.$_2$ 405 + Paris 3826 + Arg. Gen. Cat. 3442 + B.W.$_1$ 50).
32	2 49 43·64	− 5 9 59·5	Berlin Mer. Obs. AN. 2887.
33	1 50 14·22	− 7 0 33·6	Equat. comparison with B.W.$_1$ 851 and B.W.$_1$ 925.
34	1 49 12·28	− 7 8 28·9	B.W.$_1$ 851.
35	1 44 37·90	− 7 15 42·2	⅓ (Arm.$_2$ 239 + Paris 2286 + Arg. Gen. Cat. 1783). Proper motion, amounting to +0ˢ·014 in R.A. and +0″·08 in decl., is assumed provisionally by comparison with Lal. 3379 and B.W.$_1$ 765.
36	1 29 16·44	− 7 22 49·7	Equat. comparison with B.W.$_1$ 517 and B.W.$_1$ 536.
37	1 15 22·97	− 7 32 42·6	B.W.$_1$ 212.
38	0 46 14·57	− 7 44 3·4	½ (Lam. 51 + Equat. comparison with B.W.$_1$ 822).
39	0 35 14·57	− 7 43 49·8	⅓ (B.W.$_1$ 576 + Lal. 1076–7).
40	0 29 24·43	− 7 34 49·6	⅓ (B.W.$_1$ 471 + Lam. 35 + Schj. 196).
41	0 23 55·17	− 7 27 12·9	B.W.$_1$ 367.
42	0 26 6·14	− 7 26 37·1	B.W.$_1$ 400.
43	0 21 24·22	− 7 13 28·0	B.W.$_1$ 326.
	1889·0.	1889·0.	
44	0 16 55·46	− 7 15 31·0	Equat. comparison with B.W.$_1$ 265 and B.W.$_1$ 326.
45	23 52 5·39	− 6 4 36·3	½ (B.W.$_1$ 1029 + Lal. 46960).
46	23 49 41·97	− 5 31 14·2	½ (B.W.$_1$ 978 + Lal. 46879).
47	23 43 3·33	− 5 3 7·8	⅓ (2 Yarn. 10499 + B.W.$_1$ 848).
48	23 41 41	− 4 31 5	S.D.
		Comet V. 1888.	
	1888·0.	1888·0.	
49	10 3 55·28	−12 48 51·0	½ (Lal. 19796 + Lam. 653) and ½ (Lal. 19796 + B.W.$_1$ 9). The decl. of Lam. 653 is 14″·4 less, and the R.A. of B.W.$_1$ 9 is erroneous, being that of Lal. 19786, a star which precedes 21 seconds.

Comp. Star.	R.A. 1888·0.	Decl. 1888·0.	Authority.
	h m s	° ′ ″	
50	10 21 46·95	− 7 13 56·1	⅓ (B.W.$_1$ 351 + Lam. 888 + Lal. 20283).
51	10 25 22·48	− 7 3 47·1	¼ (Gr. 7 yr. 1280 + Yarn, 4377 + Glasg. 2742 + Arm.$_1$ 2286).
52	10 27 2·13	− 6 19 0·4	½ (Schj. 3861 + Equat. comparison with B.W.$_1$ 414 and B.W.$_1$ 524).
53	10 23 57·16	− 5 8 44·7	Lam. 899.
54	10 29 12·24	+ 0 14 9·9	Lam. 2989.
55	10 28 47·27	+ 2 20 29·6	¼ (Glasg. 2751 + B.W.$_1$ 473 + Lal. 20472 + Lam. 2988), using Grant's P.M.
	1889·0.	1889·0.	
56	10 28 12·25	+ 3 11 46·6	¼ (B.W.$_1$ 462 + Schj. 3865 + Lam. 273 + Lal. 20456).
57	10 24 31·98	+ 4 7 22·5	½ (B.W.$_1$ 401 + Lam. 249).
58	10 19 36·69	+ 6 25 47·5	⅓ (B.W.$_1$ 301 + Lam. 220 + Lal. 20196).
59	10 7 7·10	+17 34 11·7	½ B.W.$_2$ 108–9 + Equat. comparison with Lal. 19906).
60	10 4 3·35	+18 44 33·3	½ (B.W.$_2$ 15–16 + B.B. vi. + 18°·2326).
61	10 3 12·29	+20 52 34·2	⅓ (2 Yarn. 4224 + B.W.$_2$ 1316–7).
62	10 1 11·63	+21 42 19·5	B.B. vi. + 21°·2153.
63	9 40 2·56	+28 56 52·5	Equat. comparison with B.B. vi. + 29°·1948.
64	9 34 6·38	+32 5 44·8	Equat. comparison with B.B. vi. + 32°·1913 and 1917.
65	9 34 48·03	+32 25 14·8	B.B. vi. + 32°·1915.
66	9 31 30·96	+32 53 57·6	B.W.$_2$ 620.

Col. Tomline's Observatory, Orwell Park:
1889, *March* 18.

Errata in Professor Oudemans' Paper, Vol. xlix. No. 2.

Page 54, 4th line from bottom (of text), *for* instrumental are *read* instrumental axes.
Page 56, 7th line from bottom (of notes), *for* more than one figure *read* one figure more.
Page 59, 3rd line from bottom, *for* directions *read* direction.
Page 61, 7th line from bottom (of text), *for* limit of the moments *read* limit of the proportion between the moments.
Page 61, 2nd line from bottom (of note), *for* Beobactungen *read* Beobachtungen.

Errata in Dr. Gill's Paper, Vol. xlix. No. 3.

Page 107, 13th line from top, *for* E *read* ϵ.
Page 109, 2nd line from bottom (of note), *for* reckoning *read* revolution.
" " " " *for* round number 10′ *read* round number 10″.
Page 112, 2nd line from top, *for* rapidly *read* rigidly.